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Yields and Their Components

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YIELDS AND THEIR COMPONENTS

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1. Introduction

In this note I discuss the components of Treasury yields, most notably – the "bond risk premium" (BRP). The purpose for this is to better understand the reasons for movements in yields, since, as we will see later, different components of yields are affected by different drivers. Understanding the drivers of the yield components can then help facilitate more appropriate positioning of one's fixed income portfolio. In addition, being able to decompose the yield into pieces can be helpful in forecasting the bond's future return. Lastly, we also offer some predictions of the future path of long-term Treasury yields.

2. Components of the Yield

2.1. **Definitions.** The yield of Treasury bonds[1] can be decomposed into the following two components[2]: *expected average nominal short-term yield* and *bond risk premium (BRP)*. The first component is the market's best forecast of short-term yields over the lifetime of the bond, while the second component (BRP) is the additional compensation required by market participants for the possibility that the realized short-term yields over the lifetime of the bond might be different from the expected short-term yields at the time of the purchase of the bond. The larger the potential for the future realized yields and the expected short-term yields being different as well as the more fearful (i.e., more risk-averse) the investors feel, the larger the BRP. Thus, if the future short-term rates over the lifetime of the bond were fixed at the time of the purchase of the bond, BRP would be equal to zero. For this reason, the expected average nominal short-term yield component is sometimes referred to as the "risk-neutral yield" (see, for example, Bernanke 2015b) – the yield on a long-term Treasury bond that would be required by risk-neutral investors.[3] The expected average nominal short-term

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[1]In this article I will focus on Treasury bond yields, as they are generally viewed to have no default risk, which then simplifies the analysis. If we were to analyze a corporate bond, we would then also typically need to add a risk premium that rewards the holder of the bond for being exposed to credit risk.

[2]Please see the appendix for technical details.

[3]A risk-neutral investor is indifferent to an asset's risk and is concerned only with the expected return that the asset provides. Thus, a risk-neutral investor would only be concerned with the expected short-term yield sequence over the lifetime of the bond, rather than the potential volatility of the realized yield around this expected short-term yield estimate. In other words, a risk-neutral investor would not require additional compensation (in the form of BRP) for the risk of the realized short-term yields being different from the expected short-term yields.

yield component can be further broken down into expected average real short-term yield and the expected inflation over the lifetime of the bond.

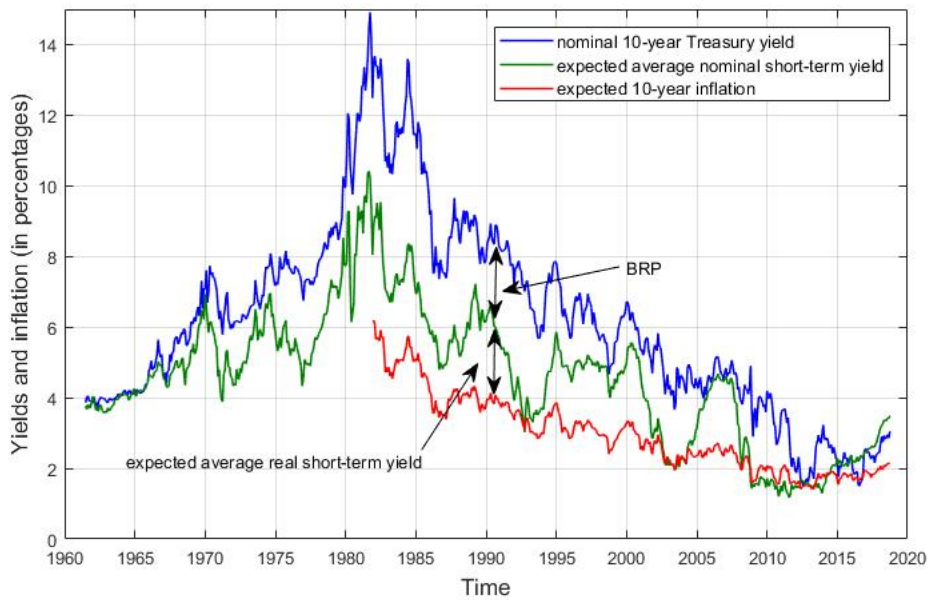

FIGURE 1. Plot of nominal 10-year Treasury yield and some of its subcomponents. Expected average nominal short-term yields are calculated using methodology in Adrian et al. (2013b) and Abrahams et al. (2015). Expected inflation is estimated using methodology in Haubrich et al. (2008). *Source: St.Louis Fed, Cleveland Fed, New York Fed, & QRG.*

It is important to note that all three components of the long-term nominal Treasury yield cannot be directly observed in the marketplace, and therefore have to be estimated. There are various theoretical as well as survey-based methods of estimating the BRP, and we will have more to say about this later on in the paper.

Figure 1 gives historical values for the 10-year Treasury yield as well as a stylistic depiction of the relationship between this yield and its components, while figure 2 gives the history of the 10-year Treasury yield as well as its three subcomponents: BRP, expected average real short-term yield and the expected inflation over the lifetime of the bond (again, the latter two sum up to the expected average nominal short-term yield).

2.2. **Historical Performance.** Next, let us see what BRP long-term bonds have garnered over time. As noted in equation 5.5 (please see the appendix), an alternative way of expressing BRP is as a difference between the expected holding period return of a long-term bond and short-term risk-free rate (also, see Cochrane (2000, p.326) and Ilmanen (2012, p.49)). Expressing the BRP this way allows us to observe the realized BRP.

Figure 3 gives the realized annual returns for Treasury bonds of various maturities over the time period of July 1961 to September 2018. Following Ilmanen (2012), we break the

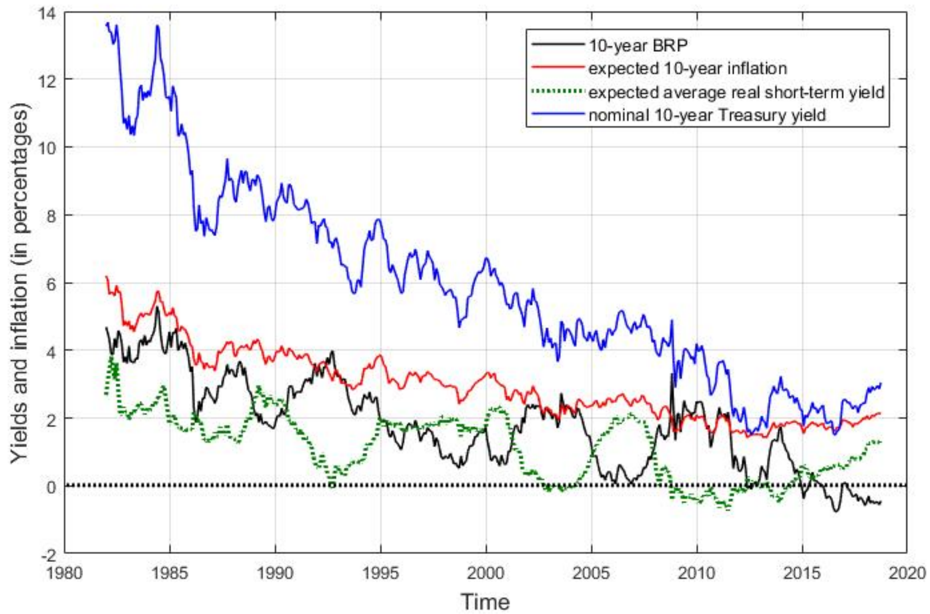

FIGURE 2. Plot of nominal 10-year Treasury yield and its three subcomponents: bond risk premia (BRP), expected average real short-term yields and expected inflation. Expected average nominal short-term yields and BRP are calculated using methodology in Adrian et al. (2013b) and Abrahams et al. (2015). Expected inflation is estimated using methodology in Haubrich et al. (2008). *Source: St.Louis Fed, Cleveland Fed, New York Fed, & QRG.*

observation period in two cycles: bond bear market (until about 1982) and bond bull market (after 1982). While the overall period gives us positive, moderate-sized realized BRP for longer duration bonds, this is not so during the bond bear market subperiod, where the realized BRP are distinctly negative. Also, during bond bull market (after 1982), the realized BRP is positive and unexpectedly large, especially for longer-maturity bonds.

The reason for large negative or positive realized (i.e., ex post) BRP has to do with the large changes in the yields over the lifetime of the bond, compared to the expected (i.e., ex ante) BRP. Case in point, as shown in figure 1, nominal 10-year yields experienced large relative changes during late 1970's and early 1980's, hitting about 14.5 percent (!) in early 1982, and then declining precipitously thereafter. These large relative changes were associated with the Fed Chairman Paul Volcker's dedicated fight to eradicate the rampant inflation of that time period from the US economy.

As a result, these large changes in the yields overwhelmed the ex ante BRPs, leading to large negative and outsized positive realized BRP. Put another way, before the peak of yields in early 1982, bond holders grossly underestimated the level of the short-term nominal yields over the lifetime of the bond (mostly due to rampant inflation and thereafter the Fed's aggressive stance against it), leading to negative realized BRP. On the other hand, after the peak of the yields in early 1982, bond holders overestimated the level of future short-term yields, leading to very large positive realized BRP, due to falling nominal yields and expected inflation. Overall,

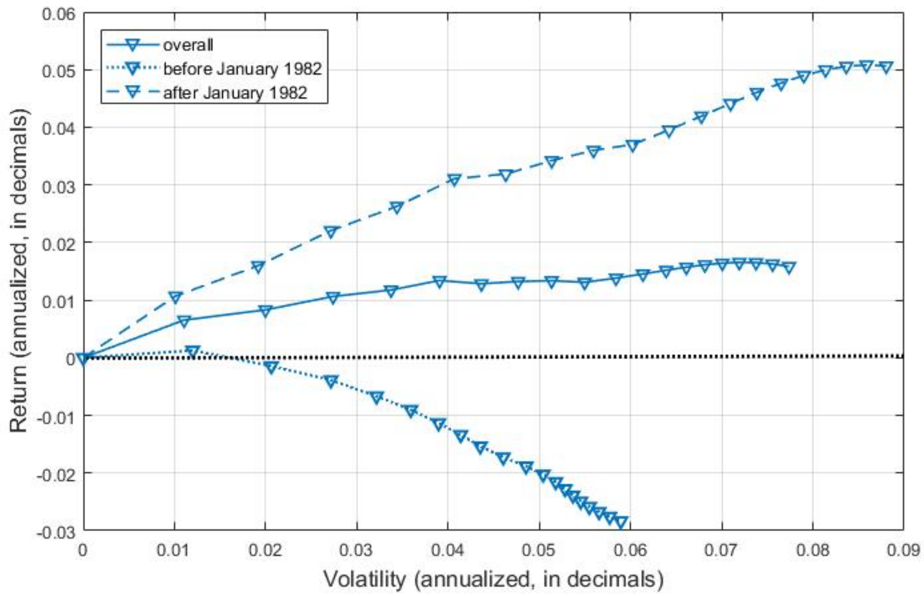

FIGURE 3. Graph of annualized average excess return versus annualized excess return volatility for various maturity (one to 20-years) Treasury securities. The excess return is calculated against a one year Treasury bond. Time periods presented: A. before January of 1982; B. after January of 1982; C. the overall time period of July of 1961 to September of 2018. *Source: St.Louis Fed & QRG.*

though, we observe an intuitive shape and level to the realized BRP structure, with the BRP being slightly increasing with bond maturity.

3. What Drives the Various Yield Components?

Next, let's turn to investigating the drivers of the bond risk premium and the expected average nominal short-term yield – the two main components of the long-term Treasury yield. The purpose of this is to better anticipate the potential moves in long-term yields and, ultimately, have the wherewithal to construct better positioned portfolios.

3.1. **Expected Average Short-Term Yield.** As noted above, the expected average nominal short-term yield component can be broken into two subcomponents: expected inflation and expected average real short-term yield.

3.1.a. *Expected Inflation.* Since Treasury bonds do not adjust their payments (coupons and face value) to the changes in inflation during the lifetime of the bond, investors need to forecast the inflation (i.e., expected inflation) as best as they can at the time of the purchase of the bond, so that this expected inflation can be included in the purchase price and reflected in its yield. A great back-of-an-envelope calculation for expected inflation is the comparison of the 10-year Treasury and 10-year TIPS yields, as the latter indexes its coupon and face value payments by the realized inflation, while the former does not. Haubrich et al. (2008) develop methodology for calculating expected inflation that adjusts the above spread for various factors, such as inflation risk premium and relative liquidity of Treasury and TIPS markets.

3.1.b. *Expected Average Real Short-term Yield.* The Federal Open Market Committee (FOMC) sets the target for the so-called Federal (or Fed) Funds Rate – the rate at which depository institutions borrow and lend to each other overnight. It also carries out open market operations (i.e., purchases and sells US Treasury instruments) to achieve this rate. Since this rate is considered the safest rate available, all other short-term risk-free rates line up closely above this rate. Thus, in principle, *by far the most important determining factor for the level of expected average real short-term Treasury yields is the sequence of future Fed Funds rates.* This is presumably also one of the reasons why so much attention is paid to the "dot plot" reports (see here for the most recent meeting), which give the assessments of future Fed Funds rates by the FOMC participants that are released on quarterly basis. However, the reflection of market's level of trust in the "dot plots" can be low (please see here). Note, for example, that the market assigns less than 20 percent likelihood, at that time of writing this, that the Fed Funds rate by the end of the next year will end up at the median (or higher) FOMC participant prediction (275-300 bps range). What the market seems to be saying is that the FOMC participants, which are the very people that are tasked with setting the monetary policy, are wrong (or at least are not being entirely forthcoming) in their assessments of where they themselves will set the rate in the future. So, how does Mr. Market come up with such bold claims?!

Part of the reason comes from the "dot plot" predictions being inaccurate, sometimes consistently and wildly so (one wonders whether the inaccuracy on the part of FOMC participants could have been intentional).[4] Perhaps the inherent inaccuracy of the "dot plot" forecasts comes from the data driven approach that FOMC takes to set the Fed Funds rates. We turn to this next, as it will shed some further light on what drives the expected average nominal short-term rates.

We need to introduce two additional concepts that will be helpful in assessing the future path of the Fed Funds Rate and, thus, the expected average short-term yield: the "Taylor rule" and the "natural rate of interest" or "r-star". The "Taylor rule" was introduced by Stanford Professor John Taylor (Taylor 1993), where he proposed a rough prescription of how Central Banks should go about setting their nominal interest rate targets. Although rarely admitted by the policy makers, the Taylor rule has arguably become a good approximation of how they do go about setting these rates. Here is the celebrated Taylor rule:

$$i_t = \pi_t + r_t^* + \alpha_\pi(\pi_t - \pi_t^*) + \alpha_y(y_t - \bar{y}_t), \tag{3.1}$$

where i_t is the prescribed nominal policy rate (such as the Fed Funds rate) at time t, π_t is the observed inflation rate at time t, r_t^* is the "equilibrium/long-term natural rate of interest" or "r-star" (much more on this later), π_t^* is the target rate of inflation (around 2

[4]This link contains information on historical "dot plots", and this site contains data on the realized Fed Funds rates. The differences between the forecasts and the realized Fed Funds rates are quite large, especially for the "dot plots" during the time periods of 2013 through 2016. Again, it is important to note that these forecasts are made by the committee members who are tasked with setting this rate.

percent for the Fed), y_t is the rate of growth in real GDP at time t, and $\bar{y}_t$ is the "potential output" – highest level of rate of growth in real GDP that could be sustained over a long term. Constants α_π and α_y were set to one half in Taylor's original work. The difference $y_t - \bar{y}_t$ is also sometimes called the "output gap", as it tracks what the economy is currently producing and what it potentially could produce. Therefore, if (as was the case after the crash of 2008) the inflation, π_t is below its target, and/or the output, y_t, is below the potential output, $\bar{y}_t$, Taylor rule captured in equation 3.1 will advocate for lower nominal policy rates, i_t, *ceteris paribus*.

While all the values in equation 3.1 can be easily observed or measured, there is one value, which cannot be directly observed or even easily estimated: r-star. As is evident from equation 3.1. it also is one of the most important inputs influencing the nominal policy rates. The concept of r-star or "equilibrium/long-term natural rate of interest" was first mentioned by Swedish economist Knut Wicksell in 1898 (Wicksell 1936), who described this concept as follows:

> *There is a certain rate of interest on loans which is neutral in respect to commodity prices, and tends neither to raise nor to lower them. ...It comes to much the same thing to describe it as the current value of the natural rate of interest on capital.*

Put another way, r-star is a long-term equilibrium interest rate that is driven by the underlying economic factors such as supply and demand of safe assets and households' attitude towards risks and uncertainties (Chen & Karp 2017); population growth, distribution of income, disinflation (Summers 2014); labor productivity growth (e.g., Yellen 2017, Bullard 2018); and labor productivity and labor force growth rate, and investor desire for safe assets (e.g., Bullard 2018, Williams 2018).

In addition, this rate is unobservable and therefore needs to be estimated. Figure 4 gives r-star estimates by two different estimation methods: Laubach & Williams (2003) and Lubik & Matthes (2015). Several important observations stand out. First, the effective real Fed Funds rate is sometimes above and sometimes below r-star. This roughly corresponds to accommodative and restrictive monetary stance by the Fed.[5] For example, the effective real Fed Funds rate was significantly higher than the r-star during the latter years of the Internet Bubble in late 1990s. On the other hand, it was significantly lower after the Internet Bubble burst and then again after the market crash of 2008. In fact, the effective real Fed Funds rate was significantly negative for almost a decade after the 2008 crash and much lower than r-star, showing the extent of the accommodative nature of recent monetary policy. Second, r-star has been declining for decades, and, as noted earlier, the list of potential culprits is long and varied. Third, over the last decade the expected average real short-term rate has diverged significantly from the real Fed Funds rate. As noted earlier, the expected average real short-term rate incorporates the market's forecast of where the short-term risk-free rate (driven largely by the Fed Funds rate) will be in the future. Thus, over the last decade the market has consistently (and to no avail) expected a future Fed Funds rate reversion to some semblance

[5]As mentioned above, the Taylor rule specifies other variables, such as current inflation versus target inflation and current output versus potential output, that are important in determining whether a particular policy rate is lax or not.

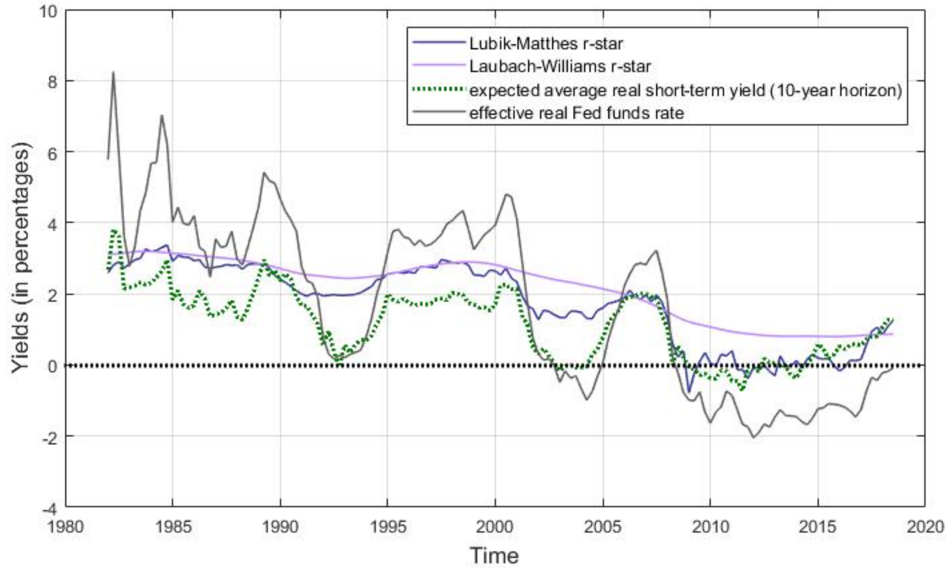

FIGURE 4. Plot of two different r-star histories along with the effective real Fed Funds rate and the expected average real short-term yield. The methodologies for r-star calculations are given in Laubach & Williams (2003) and Lubik & Matthes (2015). The methodology used for expected average short-term yield calculation is given in Adrian et al. (2013b) and Abrahams et al. (2015). *Source: St.Louis Fed, Cleveland Fed, New York Fed, Richmond Fed & QRG.*

of normalcy. While the realized Fed Rates have tended to disappoint at the beginning of this decade, the Fed has taken a much more aggressive stance as of late.

Fourth, the expected average real short-term yield seems to closely track r-star, which implies that, on average, the market expects the Fed Funds rate not to deviate far from r-star, even if the Fed pursues short-term initiatives, as dictated by the Taylor rule. Finally, figure 4 gives us the current estimate of the r-star of about (recall that these estimates come with a great deal of uncertainty, as noted earlier) of 0.9 to 1.25 percent real rate, depending on the estimate. This means that the nominal equilibrium rate is (assuming 2 percent inflation) in the 3 percent range. Now, recalling the Taylor rule (equation 3.1) and its approximate description of the relationship between the r-star and the prescribed Fed Funds rate, it is probably not entirely surprising that the median "dot plot", which gives the committee members' forecasts of the future Fed Funds rates, set at the most recent FOMC meeting for the "longer run" is exactly 3 percent.

In summary, the main driver of the expected average nominal short-term rate of return – one of two components of the long-term Treasury yield (the other being the bond risk premium) – is the Fed Funds rate, which is set by the FOMC. The Fed Funds rate, in turn, is driven by considerations that are informed by Taylor rule (see equation 3.1) type of framework. The main ingredient in the Taylor rule is the so-called r-star – an unobservable equilibrium real rate of return – which is influenced by a myriad of factors, such as households' attitude to risk, population growth, productivity growth, distribution of income and alike.

3.1.c. *Who Needs The Fed Anyway? . . .* As a side note to the above discussion, let us pursue a somewhat tongue-in-cheek line of thinking. The Federal Reserve System (or "the Fed") was established back in 1913, mainly as a bulwark against the financial crises that periodically raged in the US economy. These financial crises were usually associated with runs on banks, as there was no framework to safeguard the individual depositor in the case of a bank's insolvency. Thus, as one of the first functions assigned to the Fed was to be the "lender of the last resort," which allowed the Fed to provide credit to institutions that could not obtain credit elsewhere. The Fed also took on the function of banking regulation and supervision and facilitating the cash, check processing, electronic transfer services, and alike. So far, so good.

Finally, and this is where things start to get interesting, the Fed is assigned the task of carrying out "Monetary Policy", mainly through setting the Fed Funds rate, to pursue the dual mandate of full employment and stable prices. A natural question to ask is why not let the market set the short-term rate through a price discovery process (in which case the r-star would become observable), similar to what happens for prices of almost any other asset? By replacing the market price discovery process with an FOMC ruling, the Fed is taking on the role of a benevolent "social planner"[6] with a task of achieving an outcome that is, in some sense, more optimal than what the market could achieve on its own. To a casual observer, the main obstacle facing the FOMC in achieving this goal is the awesome complexity of the United States economy, and it is far from obvious that a group of committee members, however brilliant, would be able to steer this complex entity in the desired direction with only a handful of dials and levers.

There are additional issues that are caused by FOMC's involvement in setting the price of short-term fixed income securities. To name a few: FOMC operates under significantly incomplete information;[7] moral hazard issues[8] and the associated financial market and real economy distortions that result from the Fed coming to market's rescue, when a financial crash starts to affect the economy through "wealth effects"; the FOMC being subject to outside pressure[9] to pursue politically expedient short-term goals and, in effect, being told

[6]When I was a graduate student at an econ program, we routinely solved complex mathematical problems, where the concept of an all-knowing, all-powerful, competent, benevolent and well-intentioned "social planner" was front and center, as, under certain mathematical assumptions, this entity was able to deliver outcomes that were, in a particular mathematical sense, better than what the market participants would be able to achieve, if left to their own devices.

[7]For example, the r-star noted above, which is crucial in deciding whether the Fed Funds rate policy is accommodative or restrictive, is unobservable. In fact, research from the Richmond Fed (Lubik & Matthes 2015), demonstrates that even when we have a defensible methodology, it is extremely hard to estimate r-star precisely, as suggested by the very wide confidence intervals around the estimate.

[8]Research from the Richmond Fed suggests that the Fed's policy of dramatically reducing the Fed Fund's rate after a market crash (colloquially known as a "Greenspan put" and later as a "Bernanke put") has caused massive moral hazard. They estimate that the Fed's current explicit and implicit guarantees cover upwards of 60 percent of financial system liabilities. This number was estimated to be at about 45 percent in 1999.

[9]A textbook case for this is the showdown between the Fed Chairman Bill Martin and President Lyndon Johnson, where the latter was pushing the "Great Society" concept, along with aggressively pursuing the Vietnam War. Higher rates, as advocated by the FOMC due to the economy being in danger of overheating, where not part of LBJ's plan, so he took Chairman Martin for frequent private and not-so-private dress downs to make him see the truth.

the list of winners and losers of its monetary policy (an "independent" Fed creates this list on their own); and an assortment of unintended effects.[10]

The above issues aside, it is not even clear that the Fed's historical record of achieving a "more optimal" outcome is all that great. For example, the influential economist and Nobel Prize recipient Milton Friedman blamed the Fed for the Great Depression (Friedman & Schwartz 1963). In so many words, Ben Bernanke admitted, if facetiously, this to be the case (Bernanke 2002), noting the following:

> *Let me end my talk by abusing slightly my status as an official representative of the Federal Reserve. I would like to say to Milton and Anna: Regarding the Great Depression, you're right. We did it. We're very sorry. But thanks to you, we won't do it again.*

Since the Great Depression, we, of course, have experienced a garden variety of recessions, the latest of which was so severe that it is usually referred to as the Great Recession. While it is not an open and shut case that the Fed was, at the minimum, an accessory to the creation of the Great Recession (what with all the moral hazard that we mentioned above), the fact that this issue is being discussed in respectable circles should give pause to those advocating the Fed's omnipotence, competence and benevolence. In fact, no lesser an authority than Professor John Taylor, whom we mentioned above, laid the blame for the Great Recession at the Fed's feet (Taylor 2015).[11]

Professor Taylor also offers a solution going forward: the Fed's monetary policy needs to be rules-based. That is, one should not have to hack his way through, for example, Greenspan's "Fedspeak" – "a turgid dialect of English" as noted by Princeton University economics Professor Alan Blinder – to understand what the Fed is going to do under various economic circumstances. Instead, the monetary policy should follow a clear rules-based prescription that is known ahead of time to everyone, and which is implemented dispassionately. The public then can have a discussion about the appropriateness of these rules, but at least these rules will be well-known and expeditiously applied.

3.2. **Bond Risk Premium.** As a quick recap, the nominal long-term Treasury yield is made up of two components: expected average nominal short-term yield and bond risk premium (BRP). The first component is the market's best forecast of future short-term yields over the lifetime of the bond. If these forecasts of the future short-term yields over the lifetime of the bond were perfectly accurate, then the realized return from holding a long-term bond and rolling over a series of short-term bonds would be exactly the same. The BRP is an additional compensation required by the market participants for the possibility that the expected and realized future short-term yields might be different. *This compensation will be larger when*

[10]Lucca & Moench (2011) show that "since 1994, the S&P500 index has on average increased 49 basis points in the 24 hours before scheduled FOMC announcements. These returns do not revert in subsequent trading days and are orders of magnitude larger than those outside the 24-hour pre-FOMC window. As a result, *about 80% of annual realized excess stock returns since 1994 are accounted for by the pre-FOMC announcement drift [emphasis added].*"

[11]See Bernanke (2015a) for a rebuttal.

either the market participants become more risk averse[12]*, and/or when the potential for differences between the expected and realized future rates of return is higher* (for example, due to an unexpected spike in inflation, which changes people's expectations about the volatility of future inflation).

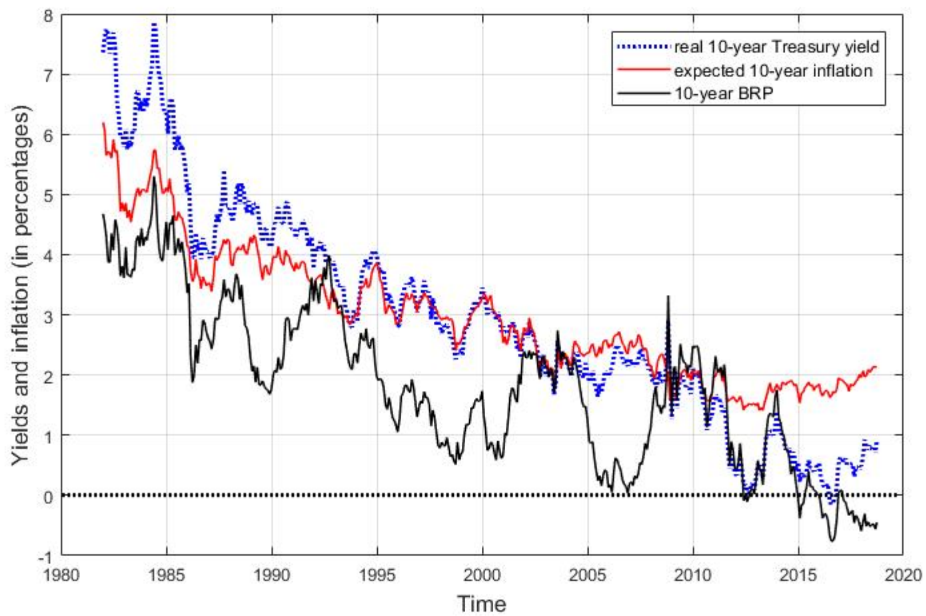

FIGURE 5. Plot of real 10-year Treasury yield, bond risk premia (BRP), and expected inflation. Expected average nominal short-term yields and BRP are calculated using methodology in Adrian et al. (2013b) and Abrahams et al. (2015). Expected inflation is estimated using methodology in Haubrich et al. (2008). *Source: St.Louis Fed, Cleveland Fed, New York Fed, & QRG.*

Thus, to understand what moves the BRP, we need to talk about what changes people's attitudes towards risk and also under what circumstances the forecasts of future expected short-term rates become more imprecise or volatile. Researchers have identified the following factors as being the main drivers of the BRP:

(i) The business cycle (e.g., Adrian, Crump, & Moench 2013a, Adrian, Crump, Mills, & Moench 2014, Ilmanen 2014). The BRP is counter-cyclical: risk premia tend to rise during economic slumps, when market participants get fearful, and decrease during economic booms, when market participants feel more confident. Note this behavior in figure 5, where the BRP tends to increase during recessions – see, for example, the dramatic spike in the BRP during the Great Recession.

[12] The risk aversion of market participants is usually counter-cyclical: it increases during recessions and declines during boom periods.

(ii) The inflation risk premium (e.g., Ilmanen 2014, Bernanke 2015b, Bauer 2017).[13] Figure 5 shows that the *real* long-term Treasury yield, which does not contain expected inflation, co-moves very strongly with it. This suggests that there is another component related to the level of expected inflation that is contained in the long-term real yield. This component is the level-dependent inflation risk premium (i.e., the higher/lower the expected inflation, the higher/lower the associated uncertainty of this inflation, which is captured by the inflation risk premium component). Also note from figure 5 that the BRP, which is one of the components of real long-term yield (the other being average expected real short-term yield), largely trends together with the long-term yield, suggesting that it is the level-dependent inflation risk premium that drives the BRP. Ilmanen (2014) notes that most of the change in the BRP overall the last several decades has been due to the reduction of inflation risk premium.[14]

(iii) Supply-demand changes (e.g., Bernanke 2015b, Bauer 2017). Treasuries have always been in a unique position and in high global demand as a safe and liquid asset. Any sudden change in the usual supply or demand can affect the BRP. A textbook example of this is the Large-Scale Asset Purchases (LSAPs) and Maturity Extension Program (MEP), colloquially known as "Quantitative Easing" and "Operation Twist", respectively. After the start of the Great Recession, in an effort to push down the long-term yields, the Fed purchased longer-term Treasury securities and agency MBS on a massive scale. Bonis, Ihrig, & Wei (2017) estimate that this resulted in reducing the long-term yields by about 100 basis points (see also Ferris, Kim, & Schlusche 2017).

(iv) Uncertainty about the future short-term rate path. Anything that clouds the future Fed Funds rate horizon will tend to increase the BRP. For example, the rate "forward guidance" tool, which communicates to the public the likely future monetary policy path (the "dot plots" we noted above, for example) will tend to decrease the uncertainty about the Fed's future monetary policies, and therefore shrink the BRP and the overall long-term yield (e.g., Bernanke 2015b, Bundick, Herriford, & Smith 2017). Also, higher dispersion of professional forecasts of the future Fed Funds rates seems to be associated with higher Treasury term premia (Adrian et al. 2013a).

Finally, let's explore the topic of whether expected BRP is predictive of future excess returns (i.e., realized BRP). Figure 6 illustrates the relationship between the ex ante (i.e., expected) BRP on a 10-year Treasury and the subsequent realized excess return (i.e., realized BRP) over a 10-year period.[15] The co-movement between the two series is very close, although their levels can be distinct for prolonger periods of time. Specifically, the realized excess

[13] Inflation risk premium refers to the compensation required by investors for the volatility in inflation. Note that this is an additional component to the expected inflation that is already built into the nominal yield. If the inflation was guaranteed to be constant over the lifetime of the bond, then inflation risk premium would be zero. The higher the forecasted uncertainty about the future inflation, the larger inflation risk premium.

[14] Ilmanen (2014, p.69) also cautions that due to the interplay between expected inflation and inflation risk premium "any future rise in inflation expectations could have a triple-whammy effect on nominal bond yields. Besides the direct inflation-expectation impact, the required BRP would rise due to a level-dependent inflation premium and a lost safe-haven value."

[15] Also, Ilmanen (2012) explores a list of potential predictors for future long-term bond excess returns and finds that BRP, along with the long-term real yield, possesses one of the highest predictive powers for future realized excess returns.

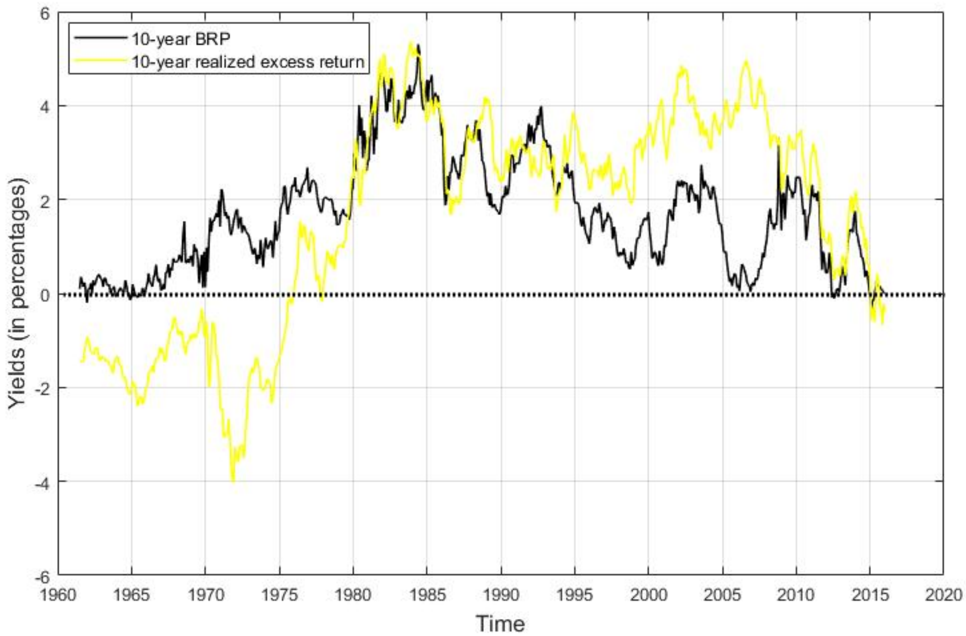

FIGURE 6. Plot of 10-year *ex-ante* BRP and the *realized* BRP (i.e., excess return) for the subsequent 10-year holding period. The BRP are calculated using methodology in Adrian et al. (2013b) and Abrahams et al. (2015). For the time period of starting with August of 2008, the realized excess return is over a period that is shorter than ten years. *Source: St.Louis Fed, New York Fed, & QRG.*

return prior to about 1982 is below the BRP preceding the holding period for the realized return, while the opposite holds for the period after 1982. We discussed the reasons for this mismatch earlier on. To reiterate, "before the peak of yields in early 1982, bond holders grossly underestimated the level of the short-term nominal yields over the lifetime of the bond (mostly due to rampant inflation and thereafter the Fed's aggressive stance against it), leading to negative realized BRP. On the other hand, after the peak of the yields in early 1982, bond holders overestimated the level of future short-term yields, leading to very large positive realized BRP, due to falling nominal yields and expected inflation."

4. Current Conditions and Predictions

I would like to end this note with some analysis of current conditions and what they portend for the future, in terms of the long-term (10-year) Treasury yield and its components.

First off, let's discuss the expected average nominal short-term rate component of the long-term Treasury yield. The current level of the expected average nominal short-term rate component is about 2.8 percent (please see figure 7).[16] Figure 8 gives the forecasted path of

[16]This version of the 10-year Treasury decomposition was carried out using methodology in Christensen & Rudebusch (2013). This methodology is slightly more conducive for the topic at hand, compared to the previous

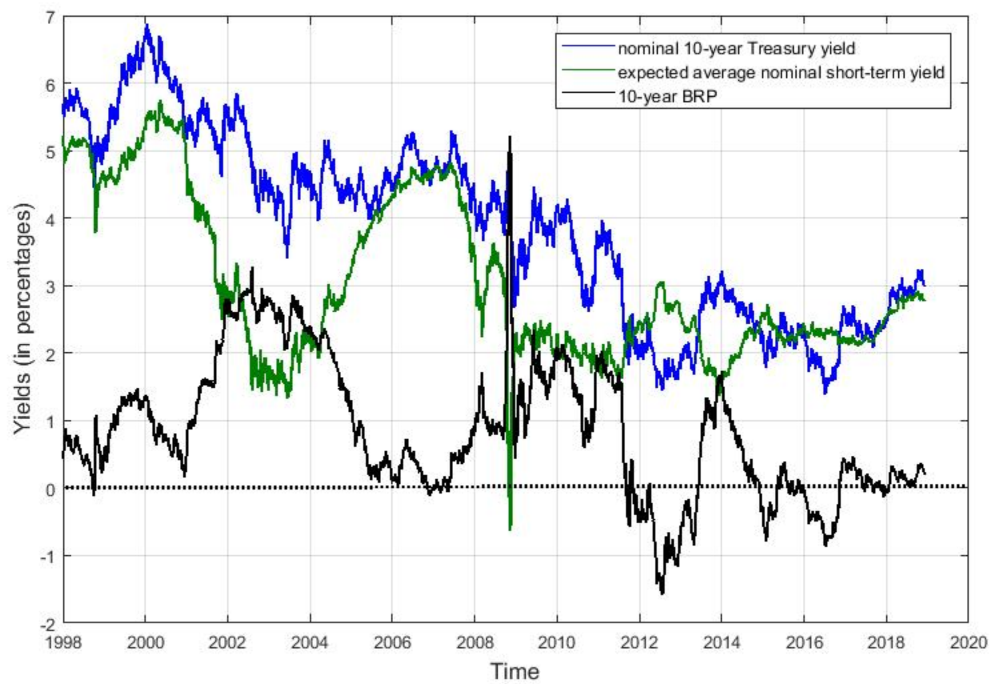

FIGURE 7. Plot of nominal 10-year Treasury yield and its subcomponents. Expected average nominal short-term yields are calculated using methodology in Christensen & Rudebusch (2013). *Source: San Francisco Fed & QRG.*

the short-term rate. Note that the shape of the path tracks the FOMC's most recent "dot plot" very closely, as would be expected, since the expected average short-term rate here is the overnight rate. Still, the rate path in figure 8 is uniformly lower than the Fed Funds rate in the "dot plot", especially in the longer term, where the median "dot plot" estimate is 3 percent, while in figure 8 the rate converges to about 2.5 percent – 50 bps lower.

The reason for this difference has to do with markets incredulity towards the "forward guidance" of the Fed's monetary policy, as captured by the "dot plots". This view is also supported by the implied probabilities that the market assigns to various levels of the future Fed Funds rates. In fact, on November 28th, 2018, Federal Reserve Chairman Jerome Powell might have proved the market right by announcing that the Fed Funds Rate is "just below the broad range of estimates of the level that would be neutral for the economy – that is, neither speeding up nor slowing down growth." Since then the 10-year Treasury yield has decreased by about 20 to 30 basis points, partly due to the adjustment in expected average

methodology by Adrian et al. (2013b) and Abrahams et al. (2015), the results of which were depicted in figures 1 and 2. The reason for this is that Christensen & Rudebusch (2013) define the short-rate to be the overnight rate, i.e., the Fed Funds rate. Adrian et al. (2013b) and Abrahams et al. (2015) use a higher maturity for their short rate definition. Thus, in principle, there can be several ways to decompose the long-term Treasury yield into components, with different values of BRP and expected average short-term rate, although all of the approaches will give estimates that have very similar trends across time, if slightly different levels.

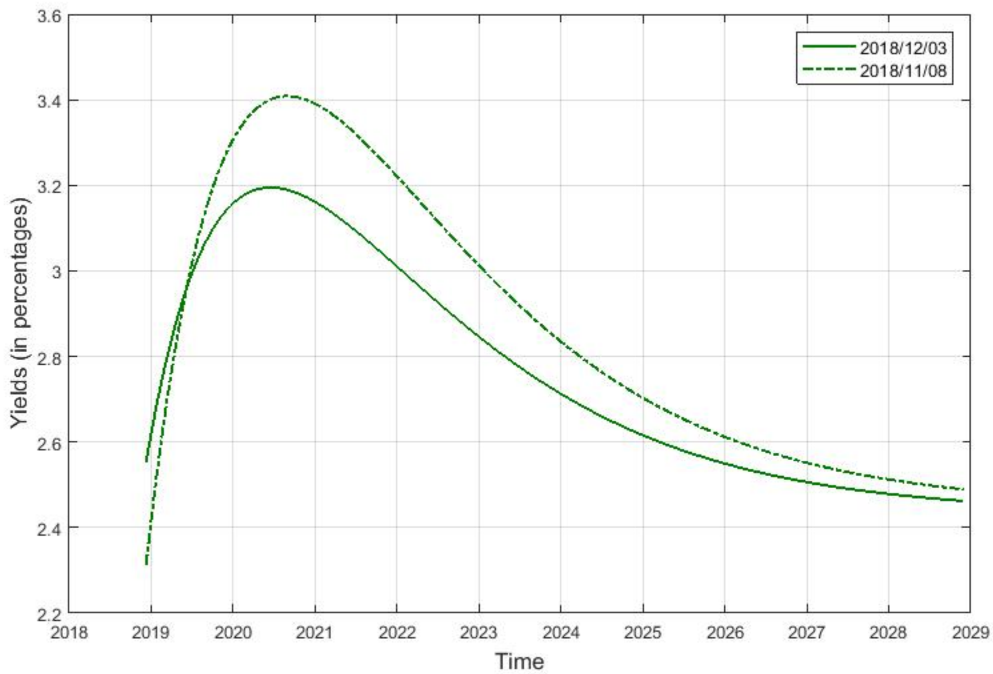

FIGURE 8. Estimated nominal short-rate future path, using methodology in Christensen & Rudebusch (2013). *Source: San Francisco Fed & QRG.*

future nominal short-rates and partly dut to the slight downward adjustment in the BRP, as market adjusts its forecasts of expected future short-term rates. This adjustment process can also be seen in figure 8, where the post-announcement locus of future rates is about 20 basis points lower than the pre-announcement locus, especially in the short-term.

Interestingly, since Chairman Powell's estimate of r-star (and therefore long-term Fed Funds target) is in the 2.25 to 2.5 percent range (the current Fed Fund's rate is in the 2 to 2.25 bps range), it is about 50 to 75 basis points lower than the long-term equilibrium rate of 3 percent that FOMC participants gave in the "dot plot". This outcome also seems to be supported by the implied probabilities that the market assigns to various levels of the Fed Funds rate during the year 2019, with the Fed Funds rate being in the 225 to 275 bps range being assigned a probability of about 70 percent.

Unless new relevant information arrives (e.g., higher-than-expected inflation) that market participants and FOMC members have not already incorporated into their forecasts, we can therefore take the "dot plots" as the ceiling on where the short-term rates will be. Therefore, it is reasonable *to peg the estimate for the expected average nominal short-term rate component of the long-term Treasury yield no higher than 2.5 to 3 percent* over the longer term. Thus, the current level of 2.8 percent for this rate is within its long-term equilibrium range.

Let us now turn to the BRP component of the long-term Treasury yield. Recall that this component of the long-term yield is affected by various factors, such as the business cycle, inflation risk premium, supply-demand changes, and uncertainty about future short-term rate path. One can only give highly speculative predictions about most of these factors, so I choose to focus on the one factor we know with much more certainty: the supply-demand changes. As noted by Bernanke (2015b), the Fed's various monetary policy interventions were quite effective in reducing the short-term as well as long-term yields. In fact, Bonis et al. (2017) estimate that the BRP was reduced by about 100 bps due to the Fed's actions that drastically expanded its balance sheet. Figure 9 portrays the massive scale of these increases [17] – from a level of slightly higher than $800 billion before the Great Recession to over $4 trillion as of now. In October of 2017 the Fed initiated a program that gradually would cease rolling over securities that mature. The Fed is using a schedule of how to affect this program (see here). At the end of this program, which should be somewhere between the first quarter of 2022 and third quarter of 2023, the remaining Treasury and MBS assets in the SOMA portfolios should be at about $2.5 trillion level, compared to the current level of $3.1 trillion. It is unclear what the Fed plans to do with the remaining $2.5 trillion of its Treasury and MBS holdings at that time. Even so, the reduction of the balance sheet by these $600 billion of Treasury and MBS holdings, is estimated (Bonis et al. 2017) to increase the BRP by about 70 bps.

Thus, to form a longer-term BRP forecast, *we should add about 70 bps to the current level of BRP (approximately 20 bps, please see figure 7), which would then give us a BRP of about 90 bps. Adding the 2.5 to 3 percent (ceiling) forecast for the expected average nominal short-term rate component to the BRP forecast gives us an overall* ***long-term nominal 10-year Treasury yield forecast of no higher than about 3.4 to 3.9 percent****.*

In our above analysis we have abstracted from various factors that, if changed from their current levels, can affect the future levels of the yields. For example, a recession (in which case the Fed cuts rates), unexpected inflation increases (in which case the Fed increases rates), geopolitical events such as an escalation in military tensions (increases in the BRP due to lower clarity of future short-rate path), and deficit issues.

In regards to the last issue, so far there have been no meaningful repercussions in the bond markets in response to the massive deficits that the US government is running. To wit, during the fiscal year 2018 that just ended, the federal debt held by the public increased by about $1.1 trillion[18], of which $780 billion was the US government deficit, compared to $666 billion last year – about 17 percent higher than last year. Interest on the existing debt added another $357 billion in 2018, compared to $296 billion last year. The total size of the US deficit[19] is almost $22 trillion. Ten years ago this number stood at $10 trillion. Only about 25 percent of the government budget consists of so-called "discretionary spending",[20] half of which is allocated to the Defense spending. It is important to note that all the political

[17] The official name for these purchases is "System of Open Market Account (SOMA) Holdings", and they constitute the asset ledger of the Fed's balance sheet. The liability side is comprised of the Reserve Balances (see here), among other things, that depository institutions maintain in their accounts at the regional branches of the Fed. When purchasing a financial asset, such as a Treasury bond, the Fed conjures up cash from thin air and uses it to purchase this asset from a depository institution, whereupon it transfers the conjured-up cash into this depository institution's account with the Fed as a payment for this asset. The purchased asset then is placed in the asset ledger of the Fed's balance sheet, while the conjured-up cash is placed in the liability ledger of the Fed's balance sheet. Also of importance, the Fed pays interest on the depository institutions' accounts with the Fed.

[18] Please see the report here.

[19] Conveniently given to the penny here.

[20] Please see a helpful infographic here for FY2017.

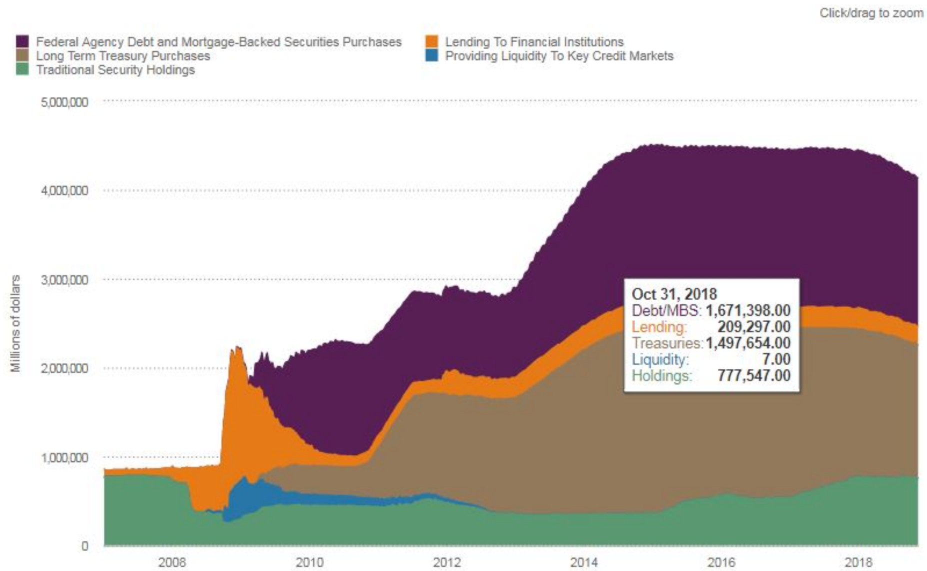

FIGURE 9. Timeline of System of Open Market Account (SOMA) Holdings: the Federal Reserve's asset ledger of the balance sheet and its components (2008 to present). *Source: Cleveland Fed. Direct link available here.*

preening and earnest utterances that we get from those in power have to do with tweaks of this 25 percent slice. The other 75 percent constitute the third rail in politics, which no politician with serious ambitions dares to touch. So far, the bond market is allowing the can to rattle down the road, but it would be a mistake, in my opinion, to assume that this will continue to be the case indefinitely. Once that happens, it is anyone's guess what the new "normal" for the yield of the long-term Treasury will be.

5. Appendix

5.1. **Definitions.** In what follows, I rely heavily on the notation and results used in Cochrane (2000). Let's define $Y_t^{(N)}$ to be the yield at time t on a Treasury bond with remaining maturity of N years; $y_t^{(N)} \equiv \log\left(1+Y_t^{(N)}\right)$ is the log yield corresponding to $Y_t^{(N)}$. Let's define the forward rate[21] at time t associated with time period $t+N$ to $t+N+1$ as follows:

$$F_t^{(N\to N+1)} = (1+Y_t^{(N+1)})^{(N+1)}/(1+Y_t^{(N)})^N - 1. \tag{5.1}$$

The log equivalent, $f_t^{(N\to N+1)} \equiv \log\left(1+F_t^{(N\to N+1)}\right)$, is then:

$$f_t^{(N\to N+1)} = (N+1)\cdot y_t^{(N+1)} - N\cdot y_t^{(N)} \tag{5.2}$$

Finally, let's define the (gross) return from holding a Treasury bond with remaining maturity of N years for one year as follows:[22]

$$R_{t+1}^{(N)} = \frac{P_{t+1}^{(N-1)}}{P_t^{(N)}} - 1,$$

where $P_t^{(N)} = 1/\left(1+Y_t^{(N)}\right)^N$. The corresponding log return is defined as $r_{t+1}^{(N)} \equiv \log(1+R_{t+1}^{(N)})$.

5.2. **Mathematical Details.** The decomposition of yields is usually presented in the context of the so-called "Expectation Hypothesis" (EH). Let's first present the EH and then discuss its implications. Per Cochrane (2000, p.326), the following three statements are equivalent and hold under EH:

1. the observed forward rate at time t (that applies to future time period from $t+k$ to $t+k+1$) equals the expected future spot rate (plus the risk premium):

$$f_t^{(k\to k+1)} = E_t\left(y_{t+k}^{(1)}\right) + BRP_k, \qquad \text{for all } k=1,\ldots,N \tag{5.3}$$

2. the observed yield at time t for a bond with N years of remaining maturity is equal to the average of expected future one-period yields (plus the risk premium):

$$y_t^{(N)} = \frac{1}{N}E_t\left(y_t^{(1)} + y_{t+1}^{(1)} + \ldots + y_{t+N-1}^{(1)}\right) + \frac{1}{N}\sum_{k=1}^{N} BRP_k \tag{5.4}$$

[21]Cochrane (2000) notes that "the forward rate is defined as the rate at which you can contract today (at time t) to borrow or lend money starting at period $t+N$, to be paid back at period $t+N+1$."

[22]Note that we are abstracting here from taking into account coupons. That is, the above algebra applies to zero-coupon bonds. The main concepts presented in this paper would be identical for a non-zero coupon bond, but, for the sake of expository simplicity, we stick with zero-coupon bonds.

3. the expected one-period return for any maturity bond is equal to the yield at time t on a bond with one year of remaining maturity (plus the risk premium):

$$(5.5) \qquad E_t\left(r_{t+1}^{(k)}\right) = y_t^{(1)} + BRP_k, \qquad \text{for all } k = 1, \ldots, N$$

where BRP_k denotes the Bond Risk Premium (BRP) associated with a bond with k years of remaining maturity.

To develop some intuition for equations 5.3 to 5.5, let's suppose for now that the bond risk premia (BRP_k) are equal to zero (incidentally, this means assuming that the so-called "pure" version EH holds). If investors are risk-neutral,[23] then they will require the same rate of return regardless of the maturity of the bond. In addition, this required rate of return will be equal to the risk-free short-term rate of return ($y_t^{(1)}$). Writing this out in notation gives us equation 5.5.

Equation 5.3 presents the same idea, only in terms of borrowing rates in the future. That is, the forward rate, $f_t^{(k\to k+1)}$, gives us the rate that we can lock into today for borrowing/lending money for some time in the future. If an investor is risk neutral, they will be indifferent (from a risk point of view) between locking their borrowing rate in today or waiting to the future time period and borrowing at the spot rate. Equation 5.3 represents this in notational terms.

Finally, using a combination of equations 5.2 and 5.3 gives us equation 5.4. That is, currently observable long-term yield is equal to the average expected future short-term spot rates.

However, Pure EH (i.e., a version of EH, where BRP_k is exactly equal to zero) is somewhat unintuitive. To wit, the yield curve is usually upward sloping, which, using equations 5.1 and 5.3, implies that market expects the future short term yields to be increasing most of the time. Perennially rising yields, or course, cannot be a natural equilibrium, as we would expect a mix of rising and falling interest rates over a long period of time. More likely, instead of investors being risk neutral, they are risk averse, which means that they view the investments represented by left and right hand sides of equations 5.3 through 5.5 as requiring different rates of returns. In other words, the BRP_k terms in equations 5.3 through 5.5 are most likely not zero. If the risk premia are not zero, but still constant through time, researchers refer to this as the "Expectations Hypothesis".

Researchers have found that asset risk premia, including bond risk premia, do change through time. We gave some evidence of this in the main text as well. Still, while 5.3 through 5.5, even with non-zero (but constant through time) risk premia, do not fit data well, these equations give a starting point for a framework to understand the mechanics of nominal yields.

5.3. **Application.** Using equation 5.4 allows us to break down the observed long-term nominal yield into expected average nominal short term rates and bond risk premia. In fact, the difference between the long-term nominal yield and the expected average nominal short term

[23] A risk-neutral investor is indifferent to an asset's risk and is concerned only with the expected return that the asset provides. In a world of risk-neutral investors, the (required) return of all the assets is the same, and it is equal to the risk-free rate of return. Intuitively, if a particular investment has a rate of return higher than the risk-free rate, other risk-neutral investors, who are indifferent to the risk of the asset, will pile into this asset until the expected rate of return for this asset has fallen to the risk-free rate of return.

rate is equal to the average of bond risk premia, where the average is over the bond risk premia given in equation 5.5, where bond risk premia corresponds to a certain maturity of the underlying bond.

Using equation 5.5 allows us to break down the expected one-period return from holding a long-term bond into a short-term risk-free rate plus bond risk premium. Thus, bond risk premium is ex-ante excess return of a long-term bond (i.e., the expected return on a long-term bond above the expected risk-free rate of return during the lifetime of the bond). Realized excess return on a long-term bond can then be viewed as the realized bond risk premium.

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